1. TITLE OF THE THESIS

"Source Apportionment of Indoor $PM_{2.5}$ using Selected Receptor Models in Different Environments"

2. INTRODUCTION

Air quality has been a cause of concern all over the world with the concentrations of criteria pollutants exceeding the standards at many places, particularly in developing countries. Particulate matter (PM) has been recognized as one of the key pollutants with adverse impact on human health, and a range of regulations have been introduced in order to control PM_{10} levels in urban areas with an increasing focus on $PM_{2.5}$ control **(Pant and Harrison, 2012)**. Over the past decades, there has been a rapid increase in urbanization and industrialization in many cities of India result a dramatic increase in number of residences, offices, buildings and manufacturing facilities, together with increase in both the number and density of motor vehicles. The urbanization process has both positive and negative effect on indoor air quality in many cities of the world **(Jones et al., 2000)**. More than 72% of the Indian households, according to census 2001, still use unprocessed biomass as their primary cooking fuel, in rural areas **(ORG, 2001)**. Air quality has been a cause of concern in Indian cities with the concentrations of criteria pollutants exceeding health-based standards, and $PM_{2.5}$ has been identified as one of the key public health concerns. High enrichment factors have been reported for various metals including Pb, Zn, Cu, Ni and Cr in a number of Indian cities, indicative of anthropogenic sources of heavy metals in particulate matter **(Kulshrestha et al., 1995; Pandey et al., 1998; Negi et al., 2002; Rastogi and Sarin, 2009)**.

Air monitoring and source apportionment of PM is mostly focused in ambient atmospheric levels in previous and current studies across the India **(Ramani et al., 2006; Chowdhury et al., 2007)** in spite of the fact that indoor $PM_{2.5}$ has shown higher correlation with adverse health effects compared to ambient $PM_{2.5}$ **(Awasthi et al., 1996; Smith, 1996; Smith, 2002; Tielsch et al., 2009; Mondal et al., 2010)**. Long-term exposure to PM results in a substantial reduction in life expectancy; greater significance to public health compared to the short-term effects **(Gong et al., 2004; Kettunen et al., 2007; Liao et al., 2009)**. $PM_{2.5}$ has shown strongest association with mortality rate and adverse effect of $PM_{2.5}$ have been summarized in earlier studies: 1) 6% increase in the risk of deaths from all causes of $10\mu g/m^3$ increase in long-term $PM_{2.5}$ concentration; 2) The estimated relative risk amounts to 12% for deaths from cardiovascular diseases and 14% for deaths from lung cancer by $10\mu g/m^3$ increase in $PM_{2.5}$ and 3) The effects related to long-term exposure include: increases in lower respiratory symptoms and chronic obstructive pulmonary disease, reductions in lung function in children and adults, and reduction in life expectancy due to cardiopulmonary mortality and lung cancer **(Tertre et al., 2002; Riediker et al., 2004; Doll et al., 2005; Sprovieri and Pirrone, 2008; Forbes et al., 2009)**. India bears one of the largest burdens of diseases due to the use of unclean household fuels. According to WHO comparative risk study, 28% of all deaths is caused by indoor air pollution (IAP) in developing countries **(WHO, 2007)**. Regional epidemiology of Chhattisgarh has shown more than three-fold increase in respiratory ailments among urban residential during 2006-2008; whereas Andhra Pradesh has shown only 19% yearly increment during this period **(Indiastat, 2008)**.

It has been calculated that about 1,361 ton/day PM emission resulting from sponge-iron industries located in Chhattisgarh **(Rao et al., 2008)**. Different variety of household fuel burning (Liquid Petroleum Gas, kerosene, coke, dung cakes, wood waste etc.) has been evaluated to be one of the major source of indoor $PM_{2.5}$ **(Kandpal et al., 1995; Mishra, 2003; Mishra et al., 2005)**. Apart from,

outdoor sources: industrial, road-traffic, soil re-suspension, constructions, biomass burning have shown proven contribution to indoors, putting it to the higher risk zone compared to outdoors **(Thornton, 1991; Li et al., 2001; Sezgin et al., 2003; Al-Khashman, 2004; Sharma and Pervez, 2004; Gadkari and Pervez, 2007; Dubey and Pervez, 2008)**. In the order to design effective programs and strategies for reduction of $PM_{2.5}$ concentration in the indoor air, it is necessary to have information about the sources and their respective contributions **(Pant and Harrison, 2012)**. The above research findings, statistics and varieties of combustion sources of $PM_{2.5}$ emissions in different environments of study region has presenting the need of source contribution investigation of indoor $PM_{2.5}$ in different environment using selected air quality receptor models.

3. A BRIEF REVIEW OF THE WORK ALREADY DONE IN THE FIELD

Characterization and spatiotemporal dispersion pattern of classified atmospheric dust fractions (PM_{10}, $PM_{2.5}$ and dusts fallout) is an important step in the development of regional air quality control strategies **(Paterson et al., 1999; Dunder and Nurdan, 2005; CPCB, 2007; 2007a; USEPA, 2008)**. Source apportionment of indoor PM has been described mostly in developed nations with variable contribution from indoor and outdoor sources **(Sexton and Hayward, 1987; Bare, 1988; Tichenor et al., 1990)**. Most of source apportionment studies on indoor PM has been conducted by executing simple factor analysis in Indian sub-continent **(Sharma and Singh, 1992; Kulshrestha et al., 2001; Tiwari et al., 2007; Kar et al., 2010; Stone et al., 2010)** and by executing effective variance-chemical Mass balance (EV-CMB) and Positive Matrix Factorization (PMF) in many developed nations **(Watson et al., 1991; Watson et al., 1994; Tsai et al., 2004;Ward and Smith, 2005; Chan et al., 2008; Ke et al., 2008; Karanasiou et al., 2009; Chen et al., 2010)**. Comparison of CMB results with PMF model has been carried out in Dhaka, Bangladesh and results have shown that, CMB provides comparable results with PMF except for limited discrepancies, especially for the $PM_{2.5}$ fractions. In case of CMB analysis, soil dust together with road dust accounted for 47.6% of the total coarse PM whereas from PMF analysis some of these factors wear just over 50% **(Begum et al., 2007)**. Coal burning and motor vehicle emission were reported to be the major source of $PM_{2.5}$ measured at Tongliang, Chongqing, China. Positive matrix factorization was use to infer the sources of $PM_{2.5}$ measure at selected urban and rural sites of Georgia and Alabama, U.S.A. Coal combustion, soils, wood smoke, secondary sulfate and ammonium nitrate where identified as major sources of $PM_{2.5}$ **(Chow et al., 2005; Liu et al., 2005)**. **Li et al., (2009),** has reported the $PM_{2.5}$ mass concentration and the chemical composition with focus on water-soluble ions and carbonaceous aerosol, as well as evaluate the likely sources of major chemical species during winter in Taingin, China and found the sum of the measured species accounted for about 60% of the $PM_{2.5}$ mass with organic aerosols and sulfates being the two largest contributors.

In India, Source apportionment studies of selected air pollution matrices have been started in earlier 2002, using internationally accepted receptor models like CMB **(Gertler et al., 2005)**. The multivariate methods; PCA being the most commonly used technique although there are some cases of application of the CMB model **(Gupta et al., 2007; Srivastava et al., 2009a; Gummeneni et al., 2011)**. One of the key reasons for use of multivariate models is the absence of local source profiles, and it is only in the recent times that source profiles have been generated for some of the sources in India. Most of the studies using CMB have used the source profiles available through the USEPA Speciate database. **Gupta et al., (2007)** prepared soil dust and road dust source profiles for Kolkata, and the recently released Central Pollution Control Board (CPCB) source apportionment study **(CPCB, 2010)** also contains India-specific source profiles for a number of sources. Use of microscopic methods has also been reported though it has not been widely applied **(Negi et al., 1987;**

Bandhu et al., 2000; Srivastava et al., 2009b). One study has been reported using PMF analysis **(Bhanuprasad et al., 2008)** although it was conducted at a regional scale (an Indian Ocean cruise) rather than at the city level. Total suspended particulate matter (TSP) and PM_{10} have been studied in great detail due to concerns over the health impacts but in recent years, the smaller size fractions of particulate matter ($PM_{2.5}$ or less) have also gained immense importance given the recent evidence of their public health implications. However, much of the research is still focused on TSP and PM_{10}, with the exception of a few cases where $PM_{2.5}$ **(Chowdhury et al., 2007; Tiwari et al., 2009; Khare and Baruah, 2010; Gummeneni et al., 2011)**.

Taneja et al., (2008), has described the indoor/outdoor relationship of fine particulates in Agra City. The most probable categories of sources for these pollutants have been identified by using principal-component analysis. Indoor air pollution is a complex function of energy housing and behavioral factors. Most dominating sources of daily average PM_{10} measured at residential and industrial sites of Calcutta have been reported to be coal combustion (42%) and vehicular emission (47%) respectively. Paved road, field burning and wood combustion contributed 21%, 7% and 1% at residential site **(Gupta, 2007)**. Most of the studies conducted earlier were related to the various size fractions of dusts known for air pollution hazards. Study of source apportionment of respirable particulate matter (PM_{10} and $PM_{2.5}$) have been initiated in six sites of India viz. Delhi, Bang lore, Pune, Kanpur, Mumbai, Chennai. Simultaneously three studies viz. (1) Development of emission factors for vehicular sources, (2) Development of source profile for vehicular sources tree and (3) Development of source profile for non-vehicular sources has also been initiated **(ARAI, 2007; CPCB 2007; 2007a)**. Apart from indoor air pollution studies, general PM monitoring studies in India describes the urban areas have shown significantly high level of atmospheric dust fallout, SPM and PM_{10} (particulate matter size, 10µ) **(Kumar et al., 2001)**. These urban areas have problems due to multiplicity and complexity of air polluting sources (Eg. industries, automobiles, generator sets, fuel burning, construction activities etc.) and even the background contribution of natural dust (Crystal origin) cannot be ruled out, particularly, in the cities developed on alluvial plans having loose top soil. The presence of a variety of complex sources of air pollution has shown the need of apportionment of these sources, for planning coast affective control strategies **(CPCB, 2007)**.

In terms of geographic distribution across the country, most of the studies have been conducted in Agra **(Kulshrestha et al., 2009; Masih et al., 2010)**. In most of the studies, a range of urban sampling sites have been used for analysis including residential, commercial, industrial, and traffic intersections/kerbside. However, there are a limited number of analyses focused on measurement and analysis between urban and background locations **(Chowdhury et al., 2007; Shridhar et al., 2010)** where results have indicated significant enrichment of trace metals in the urban environment. The Central Pollution Control Board report **(CPCB, 2010)** referred to in more detail later, is based upon detailed studies conducted in six individual cities. A whole array of element tracers has been used in India for identification of this source type including Al, Si, Ca, Ti, Fe, Pb, Cu, Cr, Ni, Co, Mg, and V **(Balachandran et al., 2000; Khillare et al., 2004; Chelani et al., 2008; Chakrobarty and Gupta, 2010; Shridhar et al., 2010; Srimuruganandam and Shiva Nagendra, 2011)**. Certain of these are rather surprising (e.g., Ni, Co and V) as their abundance in soil is low and in vehicles only modest.

4. OBJECTIVES

Goal: Evaluation of higher degree of significance in relative source contribution estimates of urban indoor $PM_{2.5}$ using selected receptor models.

Objectives:

Preparation of compositional profiles of indoor $PM_{2.5}$ in defined urban receptors.

Preparation of source compositional profiles of similar $PM_{2.5}$ fractions from various identified outdoor and indoor sources of emission.

Application of statistical receptor models [Positive Matrix Factorization (PMF 3.0) and Chemical mass balance (CMB 8)] to the prepared compositional profiles for investigation of possible source contribution.

5. NOTEWORTHY CONTRIBUTION IN THE FIELD OF THE PROPOSED WORK

The study area being selected to conduct source apportionment investigations of indoor $PM_{2.5}$ (Chhattisgarh, India) is known for biggest heavy industrial zone of India. Profuse $PM_{2.5}$ in the study region has been reported in various previous research publications and media reports. About 25 sponge-iron industries, fifties of casting and ferroalloy industries, four major cement plants, tens of major thermal power plants and an integrated steel plant are located within 200 sq km radius of the proposed study region. Source apportionment studies of $PM_{2.5}$ in classified residential-indoors at various defined sub-sectors of urban areas (residential, commercial, sensitive and industrial) **(USEPA, 2008)** will be very useful for the planning of control strategy of air pollution. Some noteworthy contributions in the field are including measurement and chemical characterization of coarse and fine particulate in ambient and indoor levels around selected industrial areas. Personal particulates (Respirable size < 5μ) have been measured in 28 adult participants longitudinally into residential areas of industrial city Bhilai, India, known for a major integrated steel plant. Source apportionment studies using CMB 8 model have shown that residential-indoors and soil-borne RPM are the major routes of personal exposure **(Gadkari and Pervez, 2007)**. Source contribution estimation of school community personal respirable particulate matter (RPM) has been investigated in Bhilai, India. 15 subjects (05 from each of three schools) were selected. The school selections were made on the basis of surrounding environmental conditions and types of air pollution sources located near the school. Major dominating sources are ambient-outdoor in case of school located near to steel plant downwind. Indoors and road-traffic dusts have also played dominating role in case of school located near to National Highway **(Gadkari and Pervez, 2008)**. Variation in relative contribution of identified sources on dust fallout measured at a residential premises among classified atmospheric receptors (ambient-outdoors, house-indoors and street-outdoors) has been reported. Road-traffic and construction activities have shown major contribution to dust fallout compared to industrial emissions **(Balakrishna and Pervez, 2009)**.

6. PROPOSED METHODOLOGY

A. AREA OF THE WORK

Raipur and Bhilai city, District of Raipur and Durg, Chhattisgarh

B. STUDY DESIGN

Ambient $PM_{2.5}$ fractions are the main outdoor precursors of high indoor air pollution, identified as key factor of adverse health problems among inhabitants of study area **(Pervez et al., 2005; 2012)**. On keeping these earlier observations, study will design in such a fashion that three main reasons of high indoor air $PM_{2.5}$ can be assessed in a scientific manner:

(1) Current status of indoor $PM_{2.5}$ in different urban residences;

(2) Identification and development of source inventories known for major contributor to indoor air;

(3) Source signatures of indoor $PM_{2.5}$.

A stratified random sampling design with longitudinal sampling plan in space-time framework will be adopted for quantification of PM levels and as well as source apportionment **(USEPA, 2003)**. Two major receptor models selected here for the study, Chemical Mass Balance (CMB 8, EPA version) and Positive Matrix Factorization (PMF 3.0, USEPA version) are based on least square and factor evaluation statistical methods, respectively. In case of CMB, prepared source profiles along with receptor compositional profiles were act as an input files for execution of the models which give relative source contribution and specific species contribution from the identified source profiles as output results, while PMF is based on factor evaluation from the input compositional profiles of receptors and factors acts as possible sources of contribution by grouping the constituents of similar uncertainty pattern. Longitudinal sampling of $PM_{2.5}$ fractions at various defined urban indoor areas can only be used for development of compositional profile which should include uncertainty for a specific receptor. Longitudinal compositional profiles of indoor $PM_{2.5}$ fractions will be used to execute PMF 3.0 and output factors (known to be possible source categories) will be compared with the number of field based visual sources known to be the possible contributors of indoor $PM_{2.5}$ for deciding the source profiles to be used in CMB execution. As per CMB model requirement, source profiles have to be prepared. Selected source profiles will be prepared using standard reported protocol and will be utilized along with indoor-receptor profiles to investigate relative source contribution of indoor $PM_{2.5}$ along with their species relative source contributions. Selection of source categories using field observations and output of PMF 3.0 will provide more precision in relative source contribution estimates by Chemical Mass Balance (CMB 8).

C. FIELD SAMPLING PLAN

The study will begin with the planning of environmental field sampling of classified $PM_{2.5}$ fractions in a space-time frame work as per the aim of objectives of this study. The environmental sampling plan has been divided into two parts: (1) Development of source profiles of $PM_{2.5}$ emissions, (2) Indoor $PM_{2.5}$, measurements and their source apportionment in defined indoor-receptors. A non-probability based stratified random sampling plan using longitudinal study design will be adopted for the collection of samples of PM fractions at classified atmospheric receptors **(Gilbert, 1987; USEPA, 2003)**.

D. PREPARATION OF SOURCE COMPOSITIONAL PROFILE OF $PM_{2.5}$

Dust emission sources in the study area will be identified using layout map of the study region, anthropogenic activity patterns and industrial and urban development plan of study area. The identified sources will be classified in point, line and regional sources of dusts emission **(USEPA, 1997; Goel and Trivedi, 1998; CPCB, 2007)**. Most of reported studies have actually explained the relative contributions of dusts from sources of specific processes viz. ferrous and non-ferrous metallurgical industries, specific type small scale industries, various vehicles exhaust, vegetative burning excluding municipal waste burning etc. Chemical characteristics of the dusts emitted from any source is depend on the ingredients of raw material consumed (in case of industries), type of mixed fuel used (in case of household fuel burning), quantity and handling of construction material (in case of urban construction) and ingredients of municipal waste burning apart from the burning temperature and other factors viz. ways of dusts formation. Surveys of the study region have shown that most of the industry type sources have consumed coal as one of the ingredient in raw material, but in different proportions. Similarly, Dust emissions from road-traffic are not only composed of automobile exhaust, but also tire particles and re-suspension of road side runoff. In most of the receptor models, co-linearity in source compositional profiles is the major disadvantage in assessment of source apportionment. The study region has three major industrial areas, namely: Siltara; Urla and Mandir Hasaud having different industrial processes in different ratios. In Siltara Industrial area, 95% industrial units are sponge iron and Ferro-alloy production; Urla Industrial area: about 55% of industrial units are ferrous metallurgical productions (sponge iron, casting, rolling mills etc) and remaining are other processes viz. textile, plastics, oil, fertilizers and chemical productions. Mandir Hasaud industrial area has only sponge iron productions. Development of source inventories of these major industrial areas by sampling $PM_{2.5}$ at downwind will provide average source profiles for these industrial areas and expected to resolve the co-linearity problem by taking different uncertainties of more indicator species of profiles. Broadly nine major group sources of $PM_{2.5}$ emission in the study region have been identified. The characteristics of selected combined sources have been presented in **Table 01.** The sampling duration, frequency will be decided using standard protocol of outdoor source sampling criteria **(USEPA, 1997; Envirotech, 2000)**. The reported criteria explained that bi-weekly measurements are most suited for any longitudinal assessments **(USEPA, 1997)**.

Table 1: Selection criteria, characteristics and type of sources known for $PM_{2.5}$ emissions. Major industrial sources of toxic loaded particulate emissions are steel, sponge iron, cement and power plants in the study region of Chhattisgarh.

Name of source &Code	Type of source & characteristics	Sampling height and location	Sampler use	Frequency
Integrated steel plant, Bhilai (S-1)	Stationary point: An integration of coke oven, Blast furnace	Down wind, height fix according to best plume reception	Combo PM_{10} & $PM_{2.5}$ sampler Ecotech Model AAS 271	10 Samples
Themal power plant, Purena (S-2)	Stationary point: Coal burning occurs	Down wind, height fix according to best plume reception		
Cement plant (S-3)	Stationary point: Coal based limestone & dolomite	Down wind, height fix according to best plume reception		
Sponge-iron, Raipur (S-4)	Stationary point: Coal, iron ore & dolomite	Down wind, height fix according to best plume reception		
Road-traffic (S-5)	Line: Automobile exhaust mixed with road side runoff	Major traffic junction, Height: 5 fit		
Civil Construction (S-6)	Area: Conventional handling of raw materials (Cement, bricks, sand)	Major colony under construction, Height: 10 fit		
Local soils (S-7)	Area: Re-suspension of soil dusts	Lab modeling, soils from 6 cm depth, ratio as per available texture in study region	PM_{10} & $PM_{2.5}$ Cyclones attached with rotary vane type pump (40 lpm)	
Residential fuel-A (S-8)	Indoor: Mixed fuel (coke, cow dung cake & wood)	Lab modeling, sampler inlet height : 2.5 ft from stove		
Residential fuel-B (S-9)	Indoor: LPG & Kerosene	Lab modeling, sampler inlet height : 2.5 ft from stove		
Municipal Waste (S-10)	Stationary point: Burning of solid inorganic, organic and bio waste	Conventional municipal waste burning places, Height: 5ft		
Total samples				100

E. CLASSIFICATION AND DEFINITION OF RECEPTOR SITE

On the basis of land use for development plan of residential activities and factors related to the transportation and dispersion pattern of atmospheric dusts, urban areas that cover **selected major city centers of Chhattisgarh (Durg-Bhilai and Raipur**) were defined as: (a) industrial and mixed use area, (b) residential and rural area, (c) sensitive area. On the basis of dust reception and activity pattern, residential-indoors have been selected from environmentally defined zones. The selection protocol of residential-indoors, sampling height, duration and frequency has been based on criteria described earlier **(CWoM, 2002; Balakrishna et al., 2004)**. Criteria for sampling duration and frequency has explained: (1) minimum three week sampling period covering winter and summer (once or twice s week) should be complete for longitudinal assessment of defined objectives; (2) a

minimum of 4-8 hr sampling duration should be incorporate to address best relation with 24 hr monitoring. **Balakrishna et al., (2004) and Kumar, (2001)**, have also addressed the description of indoor sites to be included in carrying out indoor air pollution studies viz. house characteristics, kitchen characteristics and fuel use, number of persons live, smoking habits, ventilation properties and height of indoors from outdoor surface area etc. Residential housing facilities in the study areas are mostly similar among all major cities of Chhattisgarh.

Table 2: Selection & sampling criteria for indoor receptor profiles at selected major city centers of Chhattisgarh.

Type of indoors and numbers	Sampler height from outside road	Household fuel type	Ventilation	Sampler use	Frequency of sampling	Total number of samples of $PM_{2.5}$ Fractions
Residential-Buildings (3 or 4th floor flats)-02	>12 m	LPG and kerosene	Moderate ventilation with two windows and doors	Indoor $PM_{2.5}$ Monitor (Envirotech)	20 (twice in a week, 10 in each season of winter and summer)	40
Row houses/independent bungalows: 01	~1.5 m	LPG	Well ventilation		20 (twice in a week, 10 in each season of winter and summer)	20
Slum dwellers house- 02	~1.0 m	Coke +dungcake +kerosene	Poor ventilation		20 (twice in a week, 10 in each season of winter and summer)	40
Total	100/City					

F. PREPARATION OF COMPOSITIONAL PROFILES OF SOURCE-RECEPTORS

Multiple filter samples of $PM_{2.5}$ from source and indoor sites will be collected, transported, calibrated and weighed using reported standard protocol **(Katz, 1977; Gilbert, 1987; Goel and Trivedi, 1998; Envirotech, 2000)**. The collected samples will be subjected to chemical analysis of source indicator species (OC, EC, Si, $SO_4^{=}$, Cl^-, NO_3^-, Fe, Al, Ca, Mg, Na, K, S, Cr, Mn, Ni, As, Hg, V, Zn, Cu, Pb, Co, Sb) using recommended procedures **(Katz, 1969; Chow et al., 2005; Chow et al., 2009; Kulshrestha et al., 2009; Tiwari et al., 2009; Chow and Watson, 2011).** Quartz filters will be utilized in three parts, one for OC, EC, second for ionic species and third part for elemental analysis using recommended protocol of filter analysis **(Chow and Watson, 2011)**. Speciated carbon (OC, EC) has been described to differentiate the emissions resulting from various carbon generating sources having different fuel characteristics (biomass, coal, LPG, kerosene, different mixture of ores with coal etc.) and burning temperature (steel, thermal, cement, sponge-iron, household cooking, automobile exhaust etc.). OC and EC will be determined by OC/EC analyzer (DRI Model) using thermal optical transmittance and thermal optical reflectance method and by following the recommended conditions of operation **(DRI, 2008)**. Anionic species (NH_4^+, SO_4^-, Cl^-, NO_3^-) will be analyzed in second portion of quartz filters after wet extraction by sonicators and using ion chromatographically (Dionex Model) following the recommended conditions of operation **(Canepari**

et al., 2006). The third portion of quartz/ Teflon filters will be subjected to digestion after sonnicator extraction using HNO_3 and H_2O_2 (3:1) ratio, followed by chemical analysis for selected elemental species using double beam Atomic Absorption Spectrophotometer (graphite furnace based) **(Katz, 1977; Envirotech, 2000)**. Blank filters will be used for background corrections and replicate measurements will be carried out to maintain the relative standard deviation within 5%.

G. DATA DOCUMENTATION AND SOURCE APPORTIONMENT (EXECUTION OF MODELS)

Data analysis will be performed in two parts: (1) Initial assessment of possible source categories of indoor $PM_{2.5}$ mass using $PM_{2.5}$ mass by simple regression and using chemical species concentrations & their uncertainties by positive matrix factorization (PMF 3.0) **(USEPA, 2010)**; (2) Quantification of relative source contributions of indoor $PM_{2.5}$ mass fractions by effective variance chemical mass balance (EV-CMB 8) **(Watson et al., 1997)**. Primarily the $PM_{2.5}$ data will be documented using their geometric mean and standard deviations and will compare with Indian NAAQS standards. Regression analysis between indoor $PM_{2.5}$ fractions and selected outdoor $PM_{2.5}$ fractions (source oriented S-1 to S-7) will be carried out to investigate possible relationship between source and indoors **(Geller et al., 2002)**. Further, the indoor receptor chemical profiles will be executed in PMF 3.0 to evaluate possible source categories of indoor $PM_{2.5}$ mass for selection of source profiles in quantification of relative source contributions using CMB 8. In the second part of data analysis, CMB will be executed using developed source and indoor-receptor profiles by following the recommended conditions **(Watson et al., 1997; 1998)**.

7. EXPECTED OUTCOME OF THE PROPOSED WORK

Mostly peoples are spends more than 90% of their time in indoor environments. The indoor environments of the study area are associated with higher concentration of $PM_{2.5}$ and toxic elements in $PM_{2.5}$ can increase the chance of long-term and short-term health problems for human health. Most of studies being conducted in the study region and other studies conducted in India are based on the simple ambient dust measurement which is not sufficient to relate the $PM_{2.5}$ concentration and possible health effects. Multiplicity and complexity of $PM_{2.5}$ emission sources in urban area have shown the need of source apportionment. The findings will be published in national and international journals and also through the media to evoke awareness, and ameliorate the suffering of the millions of people; most of them belong to economically poor class. The findings will be helpful to the medical professionals in the diagnosis and treatment of PM toxic related diseases and to the industrial units that may improve their emissions control system for minimizing the toxic emission. The pollution control authorities shall be better equipped with the acquired information to ensure strict implementation laws against the offensive sources of the $PM_{2.5}$ emission.

8. BIBLIOGRAPHY

Al-Khashman, O.A. **2004**. Heavy metal distribution in dust, street dust and soil from the work place in Karak Industrial Estate, Jordan. Atmospheric Environment, 38, 6803–6812.

ARAI. **2007**. Draft report on emission factor development for Indian Vehicles: Ambient air quality monitoring and emission source apportionment studies. The Automotive Research Association of India, Pune.

Awasthi, S.; Glick, H.A.; Fletcher, R.H. and Ahmed, N. **1996**. Ambient Air Pollution & Respiratory Symptoms Complex in Preschool Children. Indian Journal of Medical Research, 104, 257-262.

Balachandran, S.; Meena, B.R. and Khillare, P.K. **2000**. Particle size distribution and its elemental composition in the ambient air of Delhi. Environment International, 26, 49-54.

Balakrishna, G. and Pervez, S. **2009.** Source apportionment of atmospheric dust fallout in an urban-industrial environment in India. Aerosol and Air Quality Research, 9, 359-367.

Balakrishna, K.; Mehta, S.; Kumar, P.; Ramaswami, P.; Sambandam, S.; Kumar, K.S. and Smith, K.R. **2004**. Indoor air pollution associated with household fuel use in India: An exposure assessment and modeling exercise in rural districts of Andhra Pradesh, India. World Bank Report, ESMAP, Washington DC.

Bandhu, H.K.; Puri, S.; Garg, M.L.; Singh, B.; Shahi, J.S.; Mehta, D.; Swietlicki, E.; Dhawan, D.K.; Mangal, P.C. and Singh, N. **2000**. Elemental composition and sources of air pollution in the city of Chandigarh, India, using EDXRF and PIXE techniques. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atomsphere, 160, 126-138.

Bare, J.C. **1988**. Indoor Air Pollution Source Database. Journal of the Air Pollution Control Association, 38, 670-671.

Begum, B.A.; Biswas, S.K. and Hopke, P.K. **2007**. Source apportionment of air particulate matter by chemical mass balance (CMB) and comparison with positive matrix factorization (PMF) model. Aerosol and Air Quality Research, 7(4), 446-468.

Bhanuprasad, S.G.; Venkataraman, C. and Bhushan, M. **2008**. Positive matrix factorization and trajectory modelling for source identification: a new look at Indian Ocean experiment ship observations. Atmospheric Environment, 42, 4836-4852.

Canepari, S.; Cardarelli, E.; Giuliano, A. and Pietrodangelo, A. **2006**. Determination of metals, metalloids and non-volatile ions in airborne particulate matter by a new two-step sequential leaching procedure Part A: Experimental design and optimisation. Talanta, 69(3), 581-587.

Chakrobarty, A. and Gupta, T. **2010**. Chemical characterization of Submicron aerosol in Kanpur region: a source apportionment study. Aerosol and Air Quality Research, 10, 433-445.

Chan, Y.C.; Cohen, D.D.; Hawas, O.; Stelcer, E.; Simpson, R.; Denison, L.; Wong, N.; Hodge, M.; Comino, E. and Carswell, S. **2008**. Apportionment of sources of fine and coarse particles in four major Australian cities by positive matrix factorisation. Atmospheric Environment, 42 (2), 374-389.

Chelani, A.B.; Gajghate, D.G. and Devotta, S. **2008**. Source apportionment of PM_{10} in Mumbai, India using CMB model. Bulletin of Environmental Contamination and Toxicology, 81, 190-195.

Chen, L.-W.A.; Watson, J.G.; Chow, J.C.; DuBois, D.W. and Herschberger, L. **2010**. Chemical mass balance source apportionment for combined $PM_{2.5}$ measurements from U.S. non-urban and urban long-term networks. Atmospheric Environment, 44 (38), 4908-4918.

Chow, J.C. and Watson, J.G., **2011**. Aerosol chemical analysis on filters. In Aerosols Handbook : Measurement, Dosimetry, and Health Effects, Ruzer, L., Harley, N.H., editors. CRC Press/Taylor & Francis, New York, NY, paper accepted.

Chow, J.C.; Fairley, D.; Watson, J.G.; Demandel, R.; Fujita, E.M.; Lowenthal, D.H.; Lu, Z.; Frazier, C.A.; Long, G. and Corodova, J. **2005**. Source apportionment of PM_{10} at San Jose, Calif. Journal of Envireonmental Engineering, 0733-9372/95/0005-0378-0387.

Chow, J.C.; Watson, J.G.; Chen, L.-W.A.; Paredes-Miranda, G.; Chang, M.-C.O.; Trimble, D.; Fung, K.K.; Zhang, H. and Yu, J.Z. **2005**. Refining temperature measures in thermal/optical carbon analysis. Atmospheric Chemistry & Physics, 5 (4), 2961-2972.

Chow, J.C.; Watson, J.G.; Doraiswamy, P.; Chen, L.W.A.; Sodeman, D.A.; Lowenthal, D.H.; Park, K.; Arnott, W.P. and Motallebi, N., **2009**. Aerosol light absorption, black carbon, and elemental carbon at the Fresno Supersite, California. Atmospheric Research, 93 (4), 874-887.

Chowdhury, Z.; Zheng, M.; Schauer, J.J.; Sheesley, R.J.; Salmon, L.G.; Cass, G.R.; Russell, A.G. **2007**. Speciation of fine organic carbon particles and source apportionment of $PM_{2.5}$ in Indian cities. Journal of Geophysical Research, 112, D15303. doi:10.1029/2007JD008386.

CPCB. **2007**. A draft of conceptual guidelines and common methodology for air quality monitoring, emission inventory and source apportionment studies for Indian cities. Central Pollution Control Board, New Delhi. www.cpcb.nic.in/Air/source_ apportionment_studies.html.

CPCB. **2007a**. Model standard operating procedures (SOPs) for sampling and analysis: Air quality monitoring, emission inventory and source apportionment studies for Indian cities. Central Pollution Control Board, New Delhi. www.cpcb.nic.in/Air/source_ apportionment_studies.html.

CPCB. **2010**. Air Quality Monitoring, Emission Inventory and Source Apportionment Study for Indian Cities. Central Pollution Control Board. New Delhi.

CWoM. **2002**. Indoor air sampling and evaluation guide. WSC Policy #2-430, Office of Research and Standards, Department of Environmental Protection, Commonwealth of Massachusetts, Boston, MA, USA.

Doll, R.; Peto, R.; Boreham, J. and Sutherland, I. **2005**. Mortality in relation to alcohol consumption: A prospective study among male. British Doctors International Journal for Epidemiology, 34 (1), 199–204.

DRI. **2008**. DRI standard operating procedure: DRI Model 2001 Thermal/optical carbon analysis (TOR/TOT) of aerosol filter samples- Method IMPROVE_A. DRI SOP#2-216r2, Division of Atmospheric Sciences, Desert Research Institute, Reno, NV, USA.

Dubey, N. and Pervez, S. **2008**. Investigation of Variation in Ambient PM_{10} Levels within an Urban Industrial Environment. Aerosol and Air Quality Management, 8(1), 54-64.

Dunder, M.S. and Nurdan, D. **2005**. Heavy metal determination in outdoor atmosphere dust depositions. Fresenius Environmental Bulletin, 14(3), 185-188.

Envirotech. **2000**. Background material for short course on air quality monitoring and management, Envirotech centre for research and development, New Delhi.

Forbes, L.J.; Patel, M.D.; Rudnicka, A.R.; Cook, D.G.; Bush, T.; Stedman, J.R.; Whincup, P.H.; Strachan, D.P. and Anderson, R.H. **2009**. Chronic exposure to outdoor air pollution and markers of systemic inflammation. Epidemiology, 20(2), 245–253.

Gadkari, N. and Pervez, S. **2007**. Source Investigation of Personal Particulates in Relation to Identify Major Routes of Exposure among Urban Residentials. Atmospheric Environment, 64, 7951-7963.

Gadkari, N. and Pervez, S. **2008**. Source Apportionment of Personal Exposure of Fine Particulates among School Communities in India. Environmental Monitoring Assessment, 142, 227-241.

Geller, M.D.; Chang, M.H.; Sioutas, C.; Ostro, B.D. and Lipsett, M.J. **2002**. Indoor/Outdoor Relationship and Chemical Composition of Fine and Coarse Particles in the Southern California Deserts.

Gilbert R.O. **1987**. Statistical methods for environmental pollution monitoring, John Wiley Publication, New York.

Goel, P.K. and Trivedy, R.K. **1998**. An introduction to air pollution. Technoscience publication, Jaipur.

Gong, Jr. H.; Linn, W.S.; Terrell, S.L.; Clark, K.W.; Geller, M.D.; Anderson, K.R.; Cascio, W.E. and Sioutas, C. **2004**. Altered heart-rate variability in asthmatic and healthy volunteers exposed to concentrated ambient coarse particles. Inhalation Toxicology, 16, 335–343.

Gummeneni, S.; Yusup, Y.B.; Chavali, M. and Samadi, S.Z. **2011**. Source apportionment of particulate matter in the ambient air of Hyderabad city, India. Atmospheric Research. doi:10.1016/j.atmosres.2011.05.002.

Gupta, A.K.; Karar, K. and Srivastava, A. **2007**. Chemical mass balance source apportionment of PM_{10} and TSP in residential and industrial sites of an urban region of Kolkata, India. Journal of Hazardous Materials, 142, 279-287.

Indiastat. **2008**. State-wise number of cases and deaths due to acute respiratory infection in India: 2006-2008. Source: Ministry of Health & Family Welfare, Govt. of India, (ON74) (10443). http://www.indiastat.com/default.aspx.

Jones, N.C.; Tornton, C.A.; Mark, D. and Harrison, R.M. **2000**. Indoor /outdoor relationship of particulate matter in domestic homes with road side, urban and rural locations. Atmospheric Environment, 34, 2603-12.

Kandpal, J.B.; Maheshwari, R.C. and Kandpal, T.C. **1995**. Indoor Air Pollution From Domestic Cookstoves Using Coal, Kerosene and LPG. Energy Conversion and Management, 36, 1067-1072.

Kar, S.; Maity, J.P.; Samal, A.C. and Santra, S.C. **2010**. Metallic components of traffic-induced urban aerosol, their spatial variation, and source apportionment. Environmental Monitoring and Assessment, 168 (1-4), 561-574.

Karanasiou, A.A.; Siskos, P.A. and Eleftheriadis, K. **2009**. Assessment of source apportionment by Positive Matrix Factorization analysis on fine and coarse urban aerosol size fractions. Atmospheric Environment, 43 (21), 3385-3395.

Katz, M. **1969**. Measurement of air pollutants - guide to selection of methods. World Health Organization, Geneva, Switzerland.

Katz, M. **1977**. Methods of air sampling and analysis, American Public Health Association (APHA), Interdisciplinary Book and Periodicals, Washington D.C.

Ke, L.; Liu, W.; Wang, Y.; Russell, A.G.; Edgerton, E.S. and Zheng, M. **2008**. Comparison of $PM_{2.5}$ source apportionment using positive matrix factorization and molecular marker-based chemical mass balance. Science of the Total Environment, 394 (2-3), 290-302.

Kettunen, J.; Lanki, T.; Tiittanen, P.; Aalto, P.P.; Koskentalo, T.; Kulmala, M.; Salomaa, V. and Pekkanen, J. **2007**. Associations of fine and ultrafine particulate air pollution with stroke mortality in an area of low air pollution levels. Stroke, 38, 918–922.

Khare, P. and Baruah, B.P. **2010**. Elemental characterization and source identification of $PM_{2.5}$ using multivariate analysis at the suburban site of north-east India. Atmospheric Research, 98, 148-162.

Khillare, P.K.; Balachandran, S. and Meena, B.R. **2004**. Spatial and temporal variation of heavy metals in atmospheric aerosol in India. Environmental Monitoring and Assessment, 90, 1-21.

Kulshrestha, A.; Bisht, D.S.; Masih, J.; Massey, D.; Tiwari, S. and Taneja, A. **2009**. Chemical characterization of water-soluble aerosols in different residential environments of semi aridregion of India. Journal of Atmospheric Chemistry, 62 (2), 121-138.

Kulshrestha, A.; Satsangi, P.G.; Masih, J. and Taneja, A. **2009**. Metal concentration of $PM_{2.5}$ and PM_{10} particles and seasonal variations in urban and rural environment of Agra, India. Science of the Total Environment, 407, 6196-6204.

Kulshrestha, U.C.; Jain, M.; Sekar, R.; Vairamani, M.; Sarkar, A.K. and Parashar, D.C. **2001**. Chemical characteristics and source apportionment of aerosols over Indian Ocean during INDOEX-1999. Current Science 80 (Supplement), 180-185.

Kulshrestha, U.C.; Kumar, N.; Saxena, Kumari, K.M. and Srivastava, S.S. **1995**. Identification of the nature and source of atmospheric aerosols near the Taj Mahal (India). Environmental Monitoring and Assessment, 34, 1-11.

Kumar, P. **2001**. Characterisation of indoor respirable dust in a locality of Delhi, India. Indoor Built Environment, 10, 95-102.

Li, W.; Bai, Z.; Liu, A.; Chen, J. and Chen, L. **2009**. Characteristics of Major $PM_{2.5}$ Components during Winter in Tianjin, China. Aerosol and Air Quality Research, 9(1), 105-119.

Li, X.D.; Poon, C.S.; and Pui, S.L. **2001**. Heavy metal contamination of urban soils and street dusts in Hong Kong. Applied Geochemistry, 16, 1361–1368.

Liao, D.; Whitsel, E.A.; Duan, Y.; Lin, H.M.; Quibrera, P.M.; Smith, R.; Peuquet, D.J.; Prineas, R.J.; Zhang, Z.M. and Anderson, G. **2009**. Ambient particulate air pollution and ectopy-the environmental epidemiology of arrhythmogenesis in women's health initiative study, 1999–2004. Journal of Toxicology and Environmental Health, 72(1), 30–38.

Liu W.; Wang Y.; Russell A. and Edgerton E.S. **2005**. Atmospheric aerosol over two urban-rural pairs in the southeastern united states: Chemical composition and possible sources. Atmospheric Environment, 39, 4453-4470.

Masih, A.; Saini, R.; Singhvi, R. and Taneja, A. **2010**. Concentrations, sources, and exposure profiles of polycyclic aromatic hydrocarbons (PAHs) in particulate matter (PM10) in the north central part of India. Environmental Monitoring and Assessment, 163(1-4), 421-431.

Mishra, V. **2003**. Effect of Indoor Air Pollution From Biomass Combustion on Prevalence of Asthma in the Elderly. Environmental Health Perspective, 111, 71-77.

Mishra, V.; Smith, K.R. and Retherford, R.D. **2005**. Effects of Cooking Smoke and Environmental Tobacco Smoke on Acute Respiratory Infections in Young Indian Children. Population and Environment, 26, 375-396.

Mondal, N.K.; Mukherjee, B.; Das, D. and Ray, M.R. **2010**. Micronucleus Formation, DNA Damage and Repair in Premenopausal Women Chronically Exposed to High Level of Indoor

Air Pollution From Biomass Fuel Use in Rural India. Mutation Research-Genetic Toxicology and Environmental Mutagenesis, 697, 47-54.

Negi, B.S.; Jha, S.K.; Chavan, S.B.; Sadasivan, S.; Goyal, A.; Sapru, M.L. and Bhat, C.L. **2002**. Atmospheric dust loads and their elemental composition at a background site in India. Environmental Monitoring and Assessment, 73, 1-6.

Negi, B.S.; Sadasivan, S. and Mishra, U.C. **1987**. Aerosol composition and sources in urban areas in India. Atmospheric Environment, 21(6), 1259-1266.

ORG. **2003** (office of the registrar general). Tables on Houses, household amenities and assets. Census of India 2001, vital statistics division, office of registrar general. New Delhi, India: ministry of Home Affairs: 2003.

Pandey, P.K.; Patel, K.S. and Subrt, P. **1998**. Trace elemental composition of atmospheric particulate at Bhilai in central-east India. Science of the Total Environment, 215, 123-134.

Pant, P. and Harrison, R.M. **2012**. Critical review of receptor modelling for particulate matter: A case study of India. Atmospheric Environment, 49, 1-12.

Paterson, K.G.; Sagady, J.L.; Hooper, D.L.; Bertman, S.B.; Carroll, M.A. and Shapson, P.B. **1999**. Analysis of air quality data using positive matrix factorization. Environmental Science and Technology, 33, 635-641.

Pervez, S.; Dubey, N., Watson, J.S.; Chow, J; Pervez, Y. **2012**. Impact of household fuel use on source apportionment results of house-indoor RPM in central India. Aerosol and Air Quality Research 12, 49-60.

Pervez, S.; Mathew, J.; Sharma, R. **2005**. Investigation of personal-indoor-outdoor particulate relationships in welding workshops. Journal of Scientific & Industrial Research 64(6), 454-458.

Ramani, K.V.; Prasad, D.; Veeranna, P.; Gertler, A.; Chow, J.C.; Green, C.; Guttikunda, S.; Shah, and Sibold, K. **2006**. Source Apportionment of Air Pollutants in Hyderabad City, India. Presented at the Better Air Quality Conference, Yogyarta, Indonesia, 13–15 September 2006.

Rao, P.S.; Kumar, A.; Ansari, M.F.; Pipalatkar, P. and Chakrabarti, T. **2008**. Air Quality impact of sponge iron industries in central India. Bulletin of Environmental Contamination and Toxicology, 10.1007/s00128-008-9519-1.

Rastogi, N. and Sarin, M.M. **2009**. Quantitative chemical composition and characteristics of aerosols over western India: one-year record of temporal variability. Atmospheric Environment, 43, 3481-3488.

Riediker, M.; Cascio, W.E.; Griggs, T.R.; Herbst, M.C.; Bromberg, P.A.; Neas, L.; Williams, R.W. and Devlin, R.B. **2004**. Particulate matter exposure in cars is associated with cardiovascular effects in healthy young men. American Journal of Respiratory and Critical Care Medicine, 169, 934–940.

Sexton, K. and Hayward, S.B. **1987**. Source Apportionment of Indoor Air Pollution. Atmospheric Environment. 21, 407-418.

Sezgin, N.; Kurtulus, H.; Demir, G.; Nemlioglu, S. and Bayat, C. **2003**. Determination of heavy metal concentrations in street dust in Istanbul E-5 highway. Environment International, 29, 979–985.

Sharma, P.K. and Singh, G. **1992**. Distribution of suspended particulate matter with trace element composition and apportionment of possible sources in the Raniganj Coalfield, India. Environmental Monitoring and Assessment, 22 (2), 237-244.

Sharma, R.K. and Pervez, S. **2004**. A case study of spatial variation and enrichment of selected elements in ambient particulate matter around a large coal-fired power station in central India, Environmental Geochemistry and Health, 26(3-4), 373-381.

Shridhar, V.; Khillare, P.S.; Agarwal, T. and Ray, S. **2010**. Metallic species in ambient particulate matter at rural and urban location of Delhi. Journal of Hazardous Materials, 175, 600-607.

Smith, K.R. **1996**. Indoor Air Pollution in India. National Medical Journal of India, 9, 103-104.

Smith, K.R. **2002**. Indoor Air Pollution in Developing Countries: Recommendations for Research Indoor Air, 12, 198-207.

Sprovieri, F. and Pirrone, N. **2008**. Particle size distributions and elemental composition of atmospheric particulate matter in southern Italy. Journal of Air and Waste Management Association, 58(6), 797–805.

Srimuruganandam, B. and Shiva Nagendra, S.M. **2011**. Chemical characterization of PM (10) and PM (2.5) mass concentrations emitted by heterogeneous traffic. Atmospheric Environment 45, 3091-3102.

Srivastava, A.; Gupta, S. and Jain, V.K. **2009a**. Winter-time size distribution and source apportionment of total suspended particulate matter and associated metals in Delhi. Atmospheric Research, 92, 88-99.

Srivastava, A.; Jain, V.K. and Srivastava, A. **2009b**. SEMeEDX analysis of various size aerosols in Delhi India. Environmental Monitoring and Assessment, 150, 405-416.

Stone, E.A.; Schauer, J.J.; Pradhan, B.B.; Dangol, P.M.; Habib, G.; Venkataraman, C. and Ramanathan, V. **2010**. Characterization of emissions from South Asian biofuels and application to source apportionment of carbonaceous aerosol in the Himalayas. Journal of Geophysics Research –Atmospheres, 115.

Taneja, A.; Saini, R. and Masih, A. **2008**. Indoor Air Quality of Houses Located in the Urban Environment of Agra, India. Environmental Challenges in the Pacific Basin, 1140, 228-245.

Tertre, L.A.; Medina, S.; Samoli, E.; Forsberg, B.; Michelozzi, P.; Boumghar, A.; Vonk, J.M.; Bellini, A.; Atkinson, R.; Ayres, J.G.; Sunyer, J.; Schwartz, J. and Katsouyanni, K. **2002**. Short-term effect of particulate air pollution on cardiovascular disease in eight European cities. Journal of Epidemiology and Community Health, 56, 773–779.

Thornton, I. **1991**. Metal contamination of soils in urban area. In: P. Bullock, & P.J. Gregory (Eds.), Soil in the urban environment. Blackwell. 47–75.

Tichenor, B.A.; Sparks, L.A.; White, J.B. and Jackson, M.D. **1990**. Evaluating Sources of Indoor Air Pollution. Journal of the Air & Waste Management Association, 40, 487-492.

Tielsch, J.M.; Katz, J.; Thulasiraj, R.D.; Coles, C.L.; Sheeladevi, S.; Yanik, E.L. and Rahmathullah, L. **2009**. Exposure to Indoor Biomass Fuel and Tobacco Smoke and Risk of Adverse Reproductive Outcomes, Mortality, Respiratory Morbidity and Growth Among Newborn Infants in South India. International Journal of Epidemiology, 38, 1351-1363.

Tiwari, S.; Kulshrestha, U.C. and Padmanabhamurty, B. **2007**. Monsoon rain chemistry and source apportionment using receptor modeling in and around National Capital Region (NCR) of Delhi, India. Atmospheric Environment, 41 (27), 5595-5604.

Tiwari, S.; Srivastava, A.K.; Bisht, D.S.; Bano, T.; Singh, S.; Behura, S.; Srivastava, M.K.; Chate, D.M. and Padmanabhamurthy, B. **2009**. Black carbon and chemical characteristics of PM_{10} and $PM_{2.5}$ at an urban site of north India. Journal of Atmospheric Chemistry, 62, 193-209.

Tiwari, S.; Srivastava, A.K.; Bisht, D.S.; Bano, T.; Singh, S.; Behura, S.; Srivastava, M.K.; Chate, D.M. and Padmanabhamurty, B. **2009**. Black carbon and chemical characteristics of PM_{10} and $PM_{2.5}$ at an urban site of North India Journal of Atmospheric Chemistry, 62 (3), 193-209.

Tsai, J.; Owega, S.; Evans, G.; Jervis, R.; Fila, M.; Tan, P. and Malpica, O. **2004**. Chemical composition and source apportionment of Toronto summertime urban fine aerosol ($PM_{2.5}$). Journal of Radioanalytical and Nuclear Chemistry, 259 (1), 193-197.

USEPA. **1997**. Revised Requirements for Designation of Reference and Equivalent Methods for $PM_{2.5}$ and Ambient Air Quality Surveillance for Particulate Matter: 40 CFR Parts 53 and 58. Federal Register / Vol. 62, No. 138 / Friday, July 18, 1997 / Rules and Regulations, USA.

USEPA. **2003**. Fourth external review draft of air quality criteria for particulate matter. June-2003. USEPA/600/P-99/2aD, US Environmental Protection Agency, Washington, DC.

USEPA. **2008**. First external review draft of integrated scientific assessment of particulate matter. December-2008. USEPA/600/R-08/139. US Environmental Protection Agency, Research Triangle Park, NC.

USEPA. **2010**. EPA Positive Matrix Factorization (PMF) 3.0 model. U.S. Environmental Protection Agency, Research Triangle Park, NC. http://www.epa.gov/heasd/products/pmf/pmf.html.

Ward, T.J. and Smith, G.C. **2005**. The 2000/2001 Missoula Valley $PM_{2.5}$ chemical mass balance study, including the 2000 wildfire season - seasonal source apportionment. Atmospheric Environment, 39 (4), 709-717.

Watson, J.G. and Chow, J.C. **1986**. The potential of receptor models to apportion indoor air pollution to sources. Minneapolis, MN.

Watson, J.G.; Chow, J.C.; Lu, Z.; Fujita, E.M.; Lowenthal, D.H. and Lawson, D.R. **1994**. Chemical mass balance source apportionment of PM_{10} during the Southern California Air Quality Study. Aerosol Science and Technology, 21 (1), 1-36.

Watson, J.G.; Chow, J.C.; Richards, L.W.; Haase, D.L.; McDade, C.; Dietrich, D.L.; Moon, D.; Chinkin, L.R. and Sloane, C.S. **1991**. The 1989-90 Phoenix, AZ Urban Haze Study. Volume II: The apportionment of light extinction to sources. Report No. DRI 8931.5F1. Prepared for Arizona Department of Environmental Quality, Phoenix, AZ, by Desert Research Institute, Reno, NV.

Watson, J.G.; Robinson, N.F.; Lewis, C. and Coulter, T. **1997**. Chemical mass balance receptor model version 8 (CMB8): Users manual. Document number 1808-1D1, Desert Research Institute, US environment protection agency (USEPA).

Watson, J.G.; Robinson, N.F.; Lewis, C.W.; Coulter, C.T.; Chow, J.C.; Fujita, E.M.; Conner, T.L. and Pace, T.G. **1998**. CMB8 Applications and Validation Protocol for $PM_{2.5}$ and VOCs. Report Number 1808.2D1, Desert Research Institute.

Watson, J.G.; Robinson, N.F.; Lewis, C.W.; Coulter, C.T.; Chow, J.C.; Fujita, E.M.; Lowenthal, D.H.; Conner, T.L.; Henry, R.C. and Willis, R.D. **1997**. Chemical mass balance receptor model version 8 (CMB) user's manual. Prepared for U.S. Environmental Protection Agency, Research Triangle Park, NC, by Desert Research Institute, Reno, NV. http://eafs.sage.dri.edu/cmb80/model/.

WHO. **2007**. Indoor air pollution: national estimates of burden of diseases, http://www.who.int/indoorair/health-impacts/burden-national/en/index.html.

31/7/2012

Dr. Shamsh Pervez
Reader
School of Studies in Chemistry
Pt. Ravishankar Shukla University
RAIPUR (C.G.) 492001

SUPERVISOR **CANDIDATE**

Dr. Shamsh Pervez
Associate Professor
School of Studies in Chemistry
Raipur -492010, Chhattisgarh

Jeevan Lal Matawle

Forwarded

31-7-2012

Chairman DRC
Prof. K. S. Patel
Head
S.O.S. in Chemistry
Pt. Ravishankar Shukla University
RAIPUR (C.G.)